Efficient Routing of Intermittently Connected Mobile Networks Using Wait & Spray

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I. Abstract

Intermittently connected mobile networks are wireless networks where most of the time there does not exist a complete path from the source to the destination. There are many real networks that follow this model, for example, wildlife tracking sensor networks, military networks, vehicular ad hoc networks, etc. In this context, conventional routing schemes fail, because they try to establish complete end-to-end paths, before any data is sent.

To deal with such networks generally we use flooding-based routing schemes. While flooding-based schemes have a high probability of delivery, they waste a lot of energy and suffer from severe contention which can significantly degrade their performance. Furthermore, proposed efforts to reduce the overhead of flooding-based schemes have often been plagued by large delays. With this in mind, in this paper a new family of routing schemes that "spray" a few message copies into the network, and then route each copy independently towards the destination. If carefully designed, spray routing not only performs significantly fewer transmissions per message, but also has lower average delivery delays than existing schemes.

Index Terms

Ad hoc networks, delay tolerant networks, intermittent connectivity, routing.

II. Introduction

WIRELESS data networks often aim at extending Internet services into the wireless domain. Services like GPRS enable Internet access through the widespread cellular infrastructure, while the deployment of WiFi 802.11 access points provides direct Internet connectivity for wireless users that are within range. Additionally, self-organized ("ad hoc" or "peer-to-peer") wireless networks have been proposed for applications where setting up a supporting, wired infrastructure might be too costly or simply not an option. Despite these ongoing efforts, wireless access currently seems to give rise to inconvenience and frustration more often than providing the envisioned flexibility to the user. Cellular access is low bandwidth and expensive, while WiFi access is typically only available at a few "hotspots" that the user has to locate and move to, without real "mobile computing". The reason for these failures is that many of the assumptions made in the wired world, and which are largely responsible for the success of the Internet, do not hold in the wireless environment. The concept of a connected, stable network over which data can be routed reliably rarely holds there. Wireless signals are subject to multi-path propagation, fading, and interference making wireless links unstable and lossy. Additionally, frequent node mobility (e.g., as in vehicular ad hoc networks—VANETs) significantly reduces the time a "good" link exists, and constantly changes the network connectivity graph. As a result, wireless connectivity is volatile and usually intermittent, as nodes move in and out of range from access points or from each other, and as signal quality fluctuates. Sensor networks can significantly increase their lifetime by powering down nodes often, or by using very low power radios. This implies that many links will be down frequently, and complete end-to-end paths often will not exist. Tactical networks may also choose to operate in an intermittent fashion for LPI/LPD reasons. Finally, deep space networks and underwater networks often have to deal with long propagation delays and/or intermittent connectivity, as well. These new networks are often referred to collectively as Delay Tolerant Networks (DTN).

Under such intermittent connectivity many traditional protocols fail (e.g., TCP, DNS, etc.). It is for this reason that novel networking architectures are being pursued that could provide mobile nodes with better service under such intermittent characteristics. Arguably though, the biggest challenge to enable networking in intermittently connected environments is that of routing. Conventional Internet routing protocols (e.g., RIP and OSPF), as well as routing schemes for mobile ad hoc networks such as DSR, AODV, etc., assume that a complete path exists between a source and a destination, and try to discover these paths before any useful data is sent. Thus, if no end-to-end paths exist most of the time; these protocols fail to deliver any data to all but the few connected nodes.

However, this does not mean that packets can never be delivered in these networks. Over time, different links come up and down due to node mobility. If the sequence of connectivity graphs over a time interval is overlapped, then an end-to-end path might exist. These implies that a message could be sent over an existing link, get buffered at the next hop until the next link in the path comes up, and so on and so forth, until it reaches its destination.

III. Related Work

An approach to deal with very sparse networks or connectivity "disruptions" is to reinforce connectivity on demand. Similarly, one could force a number of specialized nodes to follow a given trajectory between disconnected parts of the network [7, 8]. In yet other cases, connectivity might be predictable, even though it's intermittent (e.g., planetary and satellite movement in Inter-planetary Networks—IPN [2]). Traditional routing algorithms could then be adapted to compute shortest delivery time paths by taking into account future connectivity [9, 10]. Nevertheless, such approaches are orthogonal but are to study what can be done when connectivity is neither enforced nor predictable, but rather opportunistic and subject to the statistics of the mobility model followed by nodes.

There exists a growing amount of work on opportunistic, DTN routing algorithms. One of the simplest approaches is to let the source or moving relay nodes carry the message all the way to the destination (Direct Transmission). Although this scheme performs only one transmission, it is extremely slow [11]. Other single-copy schemes have also been explored that can forward a message to improve end-to-end delay [1]. Yet, an even faster way to perform routing in intermittently connected mobile networks (or ICMNs), called Epidemic Routing, is to flood the message throughout the network [3]. What is worse, in realistic scenarios where bandwidth, memory space, or energy resources might be scarce, the performance of flooding degrades significantly due to congestion [4, 12].

A number of approaches have been taken to reduce the overhead

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and improve the performance of epidemic routing [13–6]. In [5] a message is forwarded to another node with some probability smaller than one. Finally, in [13] a simple method to take advantage of the history of past encounters is implemented in order to make fewer and more "informed" forwarding decisions than epidemic routing. The concept of history-based or utility-based routing is further elaborated in [4, 13] and has also been studied for regular, connected networks [14]. Finally, it has also been proposed that ideas from the area of Network Coding could be useful to reduce the number of bytes transmitted by flooding [6]. Despite the large number of existing approaches, most proposed schemes are based on epidemic-routing or some other form of controlled flooding [3, 4], and, thus, are plagued by the shortcomings of flooding-based schemes [12]. The idea of "spraying" is also not entirely new. For example, in cellular networks it has been used to deliver data to nodes that are highly mobile and change their attachment point frequently [15]. Instead of sending the message only to the base station where the node was last seen, duplicate messages are also sent to other, nearby base stations.

IV. Proposed Work

The study of single-copy routing algorithms showed that using only one copy per message is often not enough to deliver a message with high reliability and relatively small delay. Based on these observations, following desirable design goals has been identified for a routing protocol in intermittently connected mobile networks:

- perform significantly fewer transmissions than flooding based routing schemes, under all conditions.
- deliver a message faster than existing single and multi-copy schemes, and exhibit close to optimal delays.
- deliver the majority of the messages generated;
- simple, and require as little knowledge about the network as possible, in order to facilitate its implementation.

A. "Spray And Wait" Routing

Since too many transmissions are detrimental on performance, especially as the network size increases, the first protocol, Spray and Wait, distributes only a small number of copies each to a different relay. Each copy is then "carried" all the way to the destination by the designated relay.

Definition (Spray and Wait): Spray and Wait routing consists of the following two phases:

spray phase: for every message originating at a source node, message copies are initially spread forwarded by the source and possibly other nodes receiving a copy to distinct relays.

wait phase: if the destination is not found in the spraying phase, each of the nodes carrying a message copy performs "Direct Transmission" (i.e., will forward the message only to its destination).

B. "Spray and Focus" Routing

Although Spray and Wait combines simplicity and efficiency, there are some situations where it might fall short. It requires the existence of enough nodes that roam around the network often, which could potentially carry a message to a destination that lies far. Usually, Spray and Wait spreads all its copies quickly to the node's immediate neighborhood. Hence, if the mobility of each node is restricted to a small local area, then none of the nodes carrying a copy might ever see the destination.

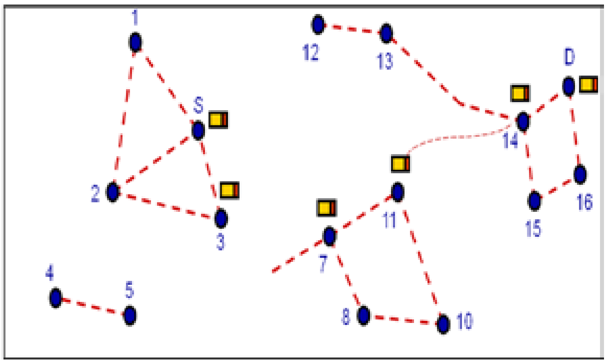
Spray and Focus: Spray and Focus routing consists of the following two phases:

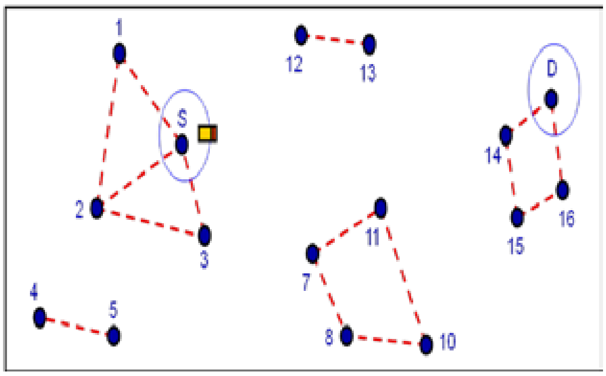
spray phase: for every message originating at a source node, message copies are initially spread forwarded by the source and possibly other nodes receiving a copy to distinct "relays".

focus phase: Let $U_X(Y)$denote the utility of node X for destination Y; a node A, carrying a copy for destination D, forwards its copy to a new node B it encounters, if and only if $U_B(D)>U_A(D)+U_{th}$, where Uth utility threshold.

An example of Intermittently Connected Mobile Networks (ICMN)

Consider an example of intermittently connected mobile networks S is the source & D is the Destination. There is no direct path from S to D In this case all the conventional protocols would fail Thus, a new routing scheme, called Spray and Wait, that "sprays" a number of copies into the network, and then "waits" till one of these nodes meets the destination.





Possible solution

Fig. Intermittently connected mobile network, Fig. After applying spray routing

V. Conclusion

In this paper, the problem of multi-copy routing in intermittently connected mobile networks is managed to overcome the shortcomings of flooding-based and other existing schemes. Deliver a message faster than existing single and multi-copy schemes, and exhibit close to optimal delays.Deliver the majority of the messages generated.

VI. Future Work

Intend to extend the analysis to cover contention for the wireless channel, and more realistic mobility models that might exhibit correlation in space and time.

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